SECONDARY BENDING MOMENT IN THE DESIGN OF BEAM WITH TRAPEZOID WEB PROFILE

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ABSTRACT

Secondary bending moment, M_{yf} is particularly occurs to corrugated web or beam with trapezoid web profile (TWP) subjected to in-plane shear force which causing flange of TWP beams to bend in lateral direction. Therefore, flange will experience double axial bending (bending in major and minor axis). This research was to seek the relationship of secondary bending moment coefficient (C_o) with the geometry of TWP beam i.e. web depth (d), web thickness (t_w), corrugation depth (hr), the width of flat sub-panel (b), and corrugation angle (α). To achieve this objective, an experimental work and also finite element have been conducted to clarify and to give clear understanding on M_{yf} and also to compare results from experiment and finite element analysis (FEA). Based on result of lateral deformation comparison between flat plate and TWP, due to inclined panel of corrugated web, TWP beam possess secondary bending moment. In this study, analysis on the secondary bending moment was made only on finite element results. The experimental result was found unreliable. In conclusion, the geometrical properties of TWP give very significant effects on the secondary bending moment except for the web thickness. The increment of hr, and b were identified to increase the C_o values while, the increment of d and α were proved to reduce the C_o values of TWP. Furthermore, the analysis using TWP without flange in finite element was found to be more appropriate.

ABSTRAK

Momen lekukan kedua (M_{yf}) hanya terjadi pada rasuk yang memiliki web yang berkerut atau web berbentuk trapezoid (TWP) yang dikenakan daya ricih yang menyebabkan bebibir mengalami lenturan pada arah mendatar. Oleh kerana itu, bebibir mengalami lenturan dua paksi (lenturan pada paksi major dan paksi minor). Kajian ini dilakukan adalah untuk mengetahui hubungan pekali momen lekukan kedua (C_o) dengan geometri TWP seperti ukur dalam web (d), ketebalan web (t_w), ukur dalam kerutan (hr), lebar sub-panel yang rata (b), dan sudut kerutan (α). Untuk mencapai objektif tersebut, eksperimen dan analisis unsur terhingga telah dijalankan untuk memberikan pemahaman yang jelas terhadap M_{yf} dan juga untuk membandingkan keputusan daripada eksperimen dan analisis unsur terhingga (FEA). Berdasarkan kepada hasil keputusan perbandingan lenturan mendatar antara plat rata dengan TWP, disebabkan terdapat panel yang serong pada web, didapati hanya TWP yang mengalami momen lekukan kedua. Dalam kajian ini, analisis tentang momen lekukan kedua hanya dilakukan pada hasil keputusan unsur terhingga. Hasil keputusan eksperimen didapati mengelirukan. Kesimpulannya, geometri TWP memberikan impak yang ketara terhadap momen lekukan kedua kecuali ketebalan web. Pertambahan hr, dan b telah dikenalpasti meningkatkan nilai C_o manakala pertambahan d dan α telah terbukti mengurangkan nilai C_o TWP. Dalam pada itu juga, analisis menggunakan TWP tanpa bebibir adalah lebih bersesuaian.

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p_y	–	Design strength
Z	–	Elastic modulus
A_{web}	–	Area of web cross-section
Q_o	–	Shear force capacity
N_o	–	Axial load capacity

CHAPTER I

INTRODUCTION

1.1 General

Beam with corrugated web is one of the enhancements in steel structural technology to eliminate some of the disadvantages using ordinary form of steel beam structure. This form of beam was introduced to optimize the use of steel section in the structures. The used of corrugated web has allowed for smaller member to carry greater load, greater span, and greater strength-to-weight ratio and offers naturally architectural design element with its own aesthetic quality.

Despite of having stiffness in order to increase the beam web capacity, corrugated web also is another alternative to create better beam section in order to increase load capacity of the section. The corrugations provide stability to the web, eliminating the need for the transverse stiffeners that have a primary influence on the shear strength of conventionally stiffened flat web plate girders.

Beam with trapezoidal web profile (TWP) consists of two flange welded to a steel web that is corrugated as shown in Figure 1.1. For this beam, the type of corrugation is trapezoid; however it could be in other form such as sinusoidal, triangular, and rectangular or any other repeating shape.

This type of structure is still on ongoing research not only in Malaysia but also in other country in order to utilize the use of high performance steel in structures. There were already many research in corrugated web with different types of scopes include research on flexural behavior (Abbas et al. 2006), shear behavior (Driver et al. 2006) fatigue life (Sause et al. 2006) and also on fabrication procedures (Sause 2003).

Apart from what have been mentions before, there are a lot of benefits and advantages of having TWP beam as a structural element. Several of the advantages are as follows:

i. The corrugated profile provides kind of continuous stiffening in the transverse direction and eventually permit the use of thin plates to achieve high carrying capacity.
ii. Reduction about 20 to 50% of weight compare to similar capacity with flat webs
iii. Smaller weight-to-strength ration induce larger clear span and resulting to cost savings.
iv. The Fatigue strength of beam with corrugated web profile can be increase up to 50% compare to beam with flat webs that are conventionally stiffened.

In this research, the focus will be on the effect of secondary moment on the beam. For ordinary I-beam, there are no significant effects of secondary moment because of the uniform cross-section along the beam. However, for the beam with trapezoid web profile, the effect of secondary moment very significant due to un-uniform cross-section of the web along the beam. The secondary bending moment will be elaborate in detailed in another chapter.

1.2 Problem Statement

The introduction of beam with trapezoid web profile (TWP) has bring a lot of benefits in optimizing the used of steel section. Trapezoidal web profile has promises greater beneficial solution in engineering practices. However, this trapezoidal profile has produce new force called secondary bending moment (M_{yf}) which is not presented in the beam with flat web profile. The information's about this still not clearly documented and adequate and still on ongoing research especially on the experimental approaches. There were few of researchers focusing about finding clear information about secondary bending moment but only based on finite element analysis.

The determination of the behavior of M_{yf} based on the geometry of the TWP beam such as web depth, flange thickness, flange width and so on using finite element analysis without having comparison with the actual result from experimental work will only resulting lower confident results. The only comparison make by them is with the German table properties for corrugated web section used by the manufactures in ensuring the result obtained is acceptable. Furthermore, the formula in determining coefficient of secondary bending moment (C_o) from previous research still need some adjustment in order to make it more simple and comfortable to be used.

Therefore, it is crucial to implement experimental work and analysis together with finite element analysis to improve or to support results from previous researches.

1.3 Objective of Study

The research based on experimental works and finite element analysis which has be conducted was to provide more information and understanding about the problem mention before and also to address several main objectives as follows:

1. To determine actual secondary bending moment, M_{yf} of TWP beams from the experimental works and finite element analysis.
2. To seek relationship between secondary bending moment coefficient, C_o with the geometry of TWP beam
3. To make comparison between actual results from experimental works and finite element analysis.

1.4 Scope of Study

The scope of the study covers the determination of lateral reaction in the flanges of TWP beam subjected to shear loading by experimental and finite element analysis. Lateral reaction obtained will determine the secondary bending moment coefficient, C_o for TWP beams according to several parametric study based on the geometry changes and eventually determine the secondary bending moment, M_{yf}. Parametric study was being carried out by varying the TWP beam geometry as follow:

i) Web depth
ii) Web thickness
iii) Corrugation depth
iv) The width of flat sub-panel
v) Corrugation angle

There was also a Comparison on the results of C_o and M_{yf} from the experimental with the finite element analysis which was based on the several parameters used in this study and also by the previous studies. Therefore, data obtained from previous researches was also being taken into account.

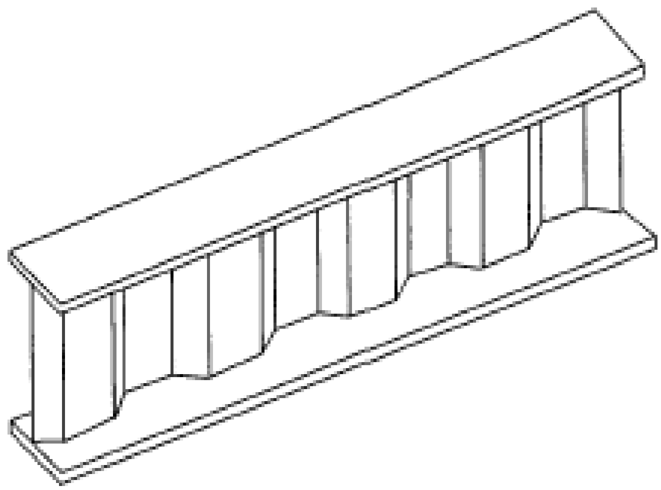

Figure 1.1: Steel beam with trapezoid web profile

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